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Comparison of the effects of different kibble shape on voluntary food intake and palatability of weight loss diets in pet dogs

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ABSTRACT

Altering characteristics of a dry proprietary diet can increase chewing, slow ingestion speed and reduce voluntary food intake. Panels of healthy research dogs consumed kibbled weight loss diets with either a l round (pastille) or a cross shape. Two panels ('small-size' panel, dogs < 10 kg 'all-size' panel, dogs with a range of sizes) were used to determine palatability (study 1), whilst a third panel ('consumption kinetics panel') was used to determine voluntary food intake [VFI] and meal duration (study 2). Study 3 was a field trial where the cross kibble was fed to client-owned overweight dogs undergoing controlled weight loss, and attitudes of owners were sort. In study 1, dogs in the all-size panel consumed more of the cross-kibble diet than of the round-kibble diet ($P < .001$), but there was no significant difference in dogs of the small-size panel ($P = 1.000$). In study 2, VFI was broadly similar for both diets, with no difference in total consumption across all four meals ($P = .370$). However, meal duration was significantly longer for the cross kibble (meal 1: 292 s; meal 2: 650 s) compared with the round kibble (meal 1: 186 s; meal 2: 282, $P < .001$ for both). In study 3, owners observed more chewing behaviour ($P = .031$), slower ingestion speed ($P = .031$), and a significant decrease in food-seeking behaviour ($P = .020$) when eating the cross-kibble compared with the round-kibble. Altering the kibble shape of a canine therapeutic weight loss diet can decrease ingestion speed without affecting palatability, but studies are now required to determine the effect on outcomes of weight management.

1. Introduction

Obesity is now an extremely common condition in dogs that is associated with increased risk, with the combined prevalence of overweight body condition affecting 56% of the pet population (Association for Pet Obesity Prevention, 2019). Given the significant impact on health and wellbeing (Lund et al., 2006; German et al., 2010a; German et al., 2012; Salt et al., 2018), the condition has formally been classified as a disease by over 20 national and international veterinary organisations (Ward et al., 2018). Weight management programmes usually involve dietary caloric restriction by feeding a purpose-formulated diet for weight loss (Laflamme and Kuhlman, 1995; Floerchinger et al., 2015) and several commercial weight loss diets are available. However, although these diets are often successful in studies undertaken in colony animals (Laflamme and Kuhlman, 1995; Borne et al., 1996; Diez et al., 2002; Floerchinger et al., 2015), they perform less well in the clinical setting (German et al., 2007 and German et al., 2015). Lack of owner compliance is thought to be one of the most common reasons for failure of weight loss programmes in clinical practice (German et al., 2015). Although commercial weight loss diets for dogs provide complete and balanced nutrition, they rely on energy restriction for their effect, which increase food-seeking behaviour, for example begging or scavenging for food, and many owners struggle to comply with dietary recommendations in the face of such behaviours (German et al., 2007 and German et al., 2015). The fact that many dogs eat rapidly, consuming the diet without chewing, might increase the owner's perception that their dog is hungry.

To address the issue of increased food-seeking behaviour during energy restriction, food manufacturers can alter macronutrient content, for example by increasing protein and fibre content (Weber et al., 2007; Hours et al., 2016). Such strategies decrease voluntary food intake (VFI) without adversely affecting palatability (Weber et al., 2007; Hours et al., 2016), thereby improving outcomes of weight loss (German et al., 2010b). Altering characteristics other than macronutrient profile can

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have a similar effect on VFI, for example using air or water to increase kibble size without increasing nutrient density are examples of such alterations (Alexander et al., 2014; Serisier et al., 2014). An alternative approach could involve altering kibble shape, since this might decrease speed of ingestion thereby increasing meal duration and reducing VFI. However, to the authors' knowledge, such an approach has not been tested experimentally. The main hypothesis of the work presented was that a cross-shaped kibble would significantly increase meal duration and decrease VFI without affecting palatability compared with a round-shaped kibble. There were two main aims: first, to determine palatability, VFI and meal duration when kibbles of different shape (round- and cross-shaped) were fed to healthy dogs from a kennel environment; and second, to determine subjective owner attitudes when feeding a crossed-shaped kibble to obese client-owned dogs already undergoing controlled weight loss using a round kibble.

2. Materials and methods

2.1. Study design and ethical considerations

Three studies were conducted to compare the performance of kibbles with two different shapes: a conventional pastille-shaped kibble (round kibble) and a cross-shaped kibble (cross kibble). Study 1 was a palatability study to compare preferences for the two different kibbles in a group of healthy dogs from a kennel environment. Study 2 was a crossover study, also undertaken in healthy kennelled dogs, to evaluate consumption kinetics for the different kibble shapes. Study 3 was a 'field evaluation' in a group of client-owned overweight dogs undergoing controlled weight loss using a therapeutic weight loss diet. The main aim of study 3 was to elicit owner opinions about the performance of the cross-kibble shape, compared with the therapeutic diet that the dog was currently on, all of which had a round shape. All experimental protocols were approved by the Royal Canin Committee for Animal Ethics and Welfare. The owners of the dogs participating in study 3 gave informed written consent.

2.2. Diets evaluated

Cross-kibble versions were created for two existing commercial dry diets formulated for weight loss, both of which were usually formulated as a conventional pastille shape (Fig. 1). The first of these diets (diet 1 [cross kibble 1, round kibble 1]) was formulated for dogs weighing ≤ 10 kg (Satiety Small Dog, Royal Canin, Aimargues, France), whilst the second (diet 2 [cross kibble 2, round kibble 2]) was formulated for dogs weighing > 10 kg (Satiety Weight Management, Royal Canin). Other than the density being decreased, the cross-kibble versions had an identical nutritional composition to their commercial round-kibble versions (Table 1).

2.3. Study animals and locations

All dogs were sourced from private breeders and were deemed to be healthy before the start of the study, based on physical examination and clinicopathological assessments (e.g., blood chemistries and complete blood counts), which were conducted on a monthly and annual basis, respectively. Dogs also remained healthy during the studies. No adverse events were reported, and no modifications of the experimental protocols were required.

Study 1 was conducted in healthy adult dogs housed at the Royal Canin Research Center, Aimargues, France, whilst study 2 was conducted in healthy adult dogs housed at the Royal Canin Research Center, Lewisburg, Ohio, United States. Housing and treatment protocols adhered to either European or USDA regulatory rules for animal welfare, as appropriate. Dogs were housed in pairs in closed indoor-outdoor runs, with an indoor kennel size of 1.52 × 2.44 m (single) or 2.44 × 2.44 m (double) and an outdoor run size of 1.52 × 3.66 m (single) or 2.44 × 3.66 m (double). For the feeding studies, all dogs were fed individually, using dividers within their own pen. Dependent on the season, the inside temperature varied between 20.0 °C and 22.7 °C. Artificial light was provided in addition to the natural light, between 06:30 and 18:30. All dogs had exercise sessions of 40–60 min per day and socialisation for 20 min per day.

Study 3 was an uncontrolled open-label observational feed trial conducted between April 2017 and July 2017. The protocol was reviewed by the Royal Canin Ethical committee. All dogs were client-owned and recruited from 10 veterinary clinics in Europe (3 in France, 3 in Germany, and 4 in the United Kingdom). Dogs were considered for inclusion in the trial if they were overweight or obese (BCS > 5/9) and, at the start of the study, were already enrolled on a controlled weight loss plan using a diet formulated for weight loss (round kibble diet 1 [30 dogs]; round kibble diet 2 [37 dogs]; diet 3 [3 dogs], Prescription Diet® Canine Metabolic Mini, Metabolic, Hill's Pet Nutrition, Topeka, KS, USA; or diet 4 [13 dogs], Prescription Diet® Canine Metabolic, Hill's Pet Nutrition). Dogs fed a diet for small dogs (i.e. < 10 kg; for example, either round kibble diet 1 or diet 3) were switched to the cross-kibble version of diet 1, whilst dogs fed a diet for large dogs (i.e. > 10 kg; for example, either round kibble diet 2 or diet 4) were switched to cross kibble diet 2. The same calorie allocation was maintained, and the

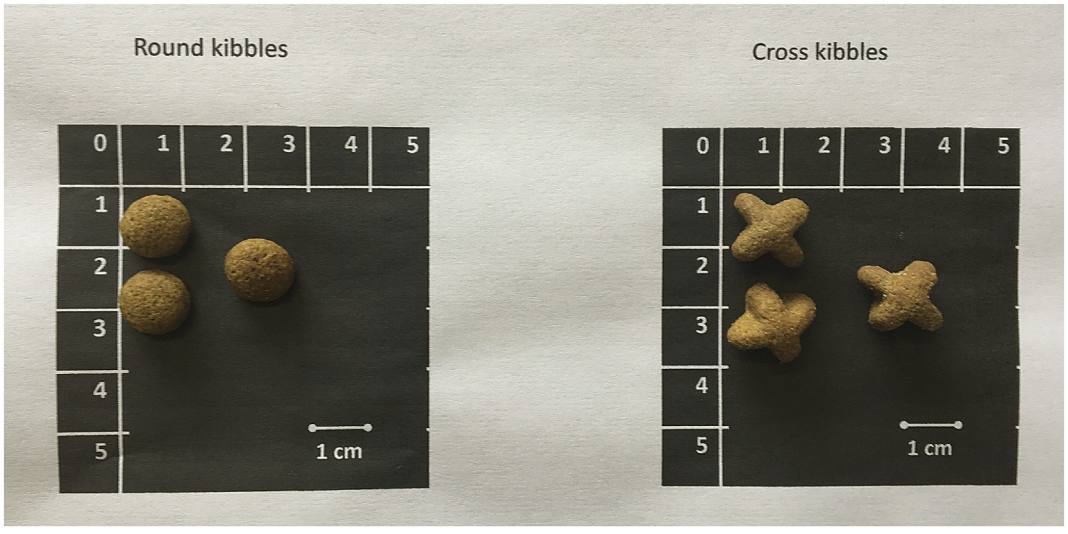

Fig. 1. Visual appearance of the round- and cross-shaped kibbles used in the current study.

Table 1
Composition and physical characteristics of the diets used in the research colony study.

Criterion	Diet 1		Diet 2	
ME content[a]	2662 kcal/kg		2978 kcal/kg	
Analytics	Per 100 g AF	g/1000 kcal	Per 100 g AF	g/1000 kcal
Moisture	9.5	3.57	9.5	3.55
Protein	30.0	11.3	30.0	11.2
Fat	9.5	3.6	9.5	3.6
Crude fibre	15.8	6.0	16.8	6.3
TDF	27.8	10.4	28.1	10.5
NFE	28.2	10.6	28.4	10.6
Ash	6.7	2.6	5.8	2.2
Density	**Round:** 330 g/L		**Round:** 315 g/L	
	Cross: 300 g/L		**Cross:** 295 g/L	
Ingredients	Vegetable fibre, dehydrated poultry protein, wheat gluten, tapioca, chicory pulp, hydrolysed animal proteins, maize gluten, wheat, maize, animal fats, minerals, psyllium husks and seeds, fish oil, fatty acid salt, fructo-oligosaccharides, hydrolysed crustaceans (source of glucosamine), marigold extract (source of lutein), hydrolysed cartilage (source of chondroitin)		Vegetable fibre, dehydrated poultry protein, wheat gluten, tapioca, maize gluten, hydrolysed animal proteins, wheat, maize, animal fats, beet pulp, fish oil, minerals, fructo-oligosaccharides, psyllium husks and seeds, soya oil, hydrolysed crustaceans (source of glucosamine), marigold extract (source of lutein), hydrolysed cartilage (source of chondroitin)	

[a] Metabolisable energy content for each diet was calculated using Modified Atwater factors, based on the declared average dietary composition information for each diet. AF: as fed; NFE: nitrogen free extract; TDF: total dietary fibre. Diet 1: Satiety Small Dog, Royal Canin, Aimargues, France. Diet 2: Satiety Weight Management, Royal Canin, Aimargues, France.

kibble diet was fed for a 2-week period. During the study, all dogs were housed at home with no changes made to their conditions.

2.4. Study 1: palatability

Palatability was assessed in two dog panels: a small-size panel, comprising 32 dogs ≤10 kg, and an all-size panel comprising 35 dogs of a range of sizes and weights. All dogs in the small-size panel were female, comprising 11 different breeds (7 Yorkshire terrier, 6 Tibetan spaniel, 4 Podengo portuges, 3 Long-haired dachshund, 3 Smooth-haired dachshund, 2 German spitz, 2 Miniature schnauzer, 2 Papillon dog, 1 Shih Tzu, 1 Wire-haired dachshund and 1 Italian greyhound). Median age was 4 years (range 2 to 7 years), median weight was 4.87 kg (range 2.88 kg to 7.42 kg), and body condition score (BCS) was 5 for all dogs, on a nine-unit scale (Laflamme, 1997). The dogs in the all-size dog panel were The 35 dogs weighing > 10 kg were all female, and comprised 17 different breeds (6 English setter, 3 German shepherd dog, 2 Australian shepherd dog, 2 Basset fauve de Bretagne, 2 Cairn terrier, 2 Drahthaar, 2 English cocker spaniel, 2 English springer spaniel, 2 Giant schnauzer, 2 Gordon setter, 2 Parson Russel Terrier, 2 West Highland white terrier, 2 Wire-haired dachshund, 1 Beauceron, 1 Brittany spaniel, 1 Podengo portuges and 1 Visigoths spitz). Median age was 5 years (range 2 to 7 years), median weight was 16.95 kg (range 6.22 kg to 38.24 kg), median body condition score (BCS) was 5/9 (range 4/9 to 6/9).

Dogs were individually offered a bowl of the cross kibble diet and a bowl of the round kibble diet, with either diet 1 (for dogs < 10 kg) or diet 2 (for dogs > 10 kg) used dependent on the size of the dog. Bowls were identical in shape, colour and size, and were placed side-by-side. The amount offered in each bowl was equivalent to half of the daily energy requirements for each dog (55 kcal/kg$^{0.75}$). When dogs had eaten half of the food offered, bowls were withdrawn, so that dogs did not consume more than their daily requirements. The protocol was performed twice on the same day, at 9:00 and 16:00.

2.5. Study 2: consumption kinetics

Consumption kinetics were studied by measuring both VFI and meal duration in a separate panel, the consumption kinetics panel, which comprised 24 neutered dogs (11 male, 13 female) of 4 different breeds (17 Labrador retrievers, 3 Brittany spaniels, 2 standard poodles, 2 beagles). A power calculation was not performed because, unfortunately, no pilot data were available for consumption kinetics for diets with different kibble shape, meaning that a meaningful estimate the likely effect size was not possible. Instead, 24 dogs were used, which was twice as many as for a recent study of consumption kinetics of different therapeutic diets in kennelled dogs (Hours et al., 2016). Median age was 3 years (range, 2 to 8 years), median weight was 24.9 kg (range 10.2 kg to 32.7 kg), median BCS was 5/9 (range 4/9 to 6/9). The dogs were assigned to two comparable groups based on BCS, and the diets used were the same as for the palatability study (e.g. the cross-shaped or round-shaped versions of diet 2). Dogs were fed each diet for 7 days, using a crossover design (Fig. 2), with half the dogs receiving the round kibble first, and the other half receiving the cross kibble first. The order of the diets was not randomly determined but, instead, arbitrarily decided in advance by the researchers. The test protocol was performed on 3 non-consecutive days for each study period, with food intake reduced to 80% of MER for the days in between study periods. Given that the formulation of the two diets were similar, the 2 periods ran consecutively with no adaptation period between diets. However, before the start of each period, all dogs were familiarised to both diets, by offering each at 80% MER for 2 days. On test days, consumption kinetics were assessed through repeated short-term food exposure, using a modification of a protocol previously described (Weber et al., 2007; Hours et al., 2016). Briefly, each dog was offered the food at 100% MER for a 15-min period over 4 consecutive meals separated by 45-min intervals. Water was available ad libitum throughout the feeding period. Voluntary food intake (in kcal/kg$^{0.75}$) was measured for all 4 meals, each trial day, per diet for each dog. However, only the duration (in seconds) of the first two meals of the consumption kinetics study were measured, because dogs did not consume all of the food available in meals 3 and 4.

2.6. Study 3: field evaluation

The field evaluation involved 83 client-owned dogs already undergoing weight management using therapeutic weight loss diets, all of which had a round kibble shape (Table 2). For the same reasons as before, a formal power calculation was not feasible and, instead, as many dogs as possible were included during the study timeframe. At the start of the study period, before the new diet was fed, owners were asked to consider chewing behaviour, speed of ingestion and various food-seeking behaviours (e.g. rapid consumption of food, vocalising for food, “stealing” food, raiding bins, waking the owner during the night for food, staying near the food bowl, or being aggressive over food). The owner was then asked to rate the degree that their dog displayed these behaviours on a 4-point ordinal scale (Table 3).

Owners then introduced the cross-kibble diet and fed it for a period

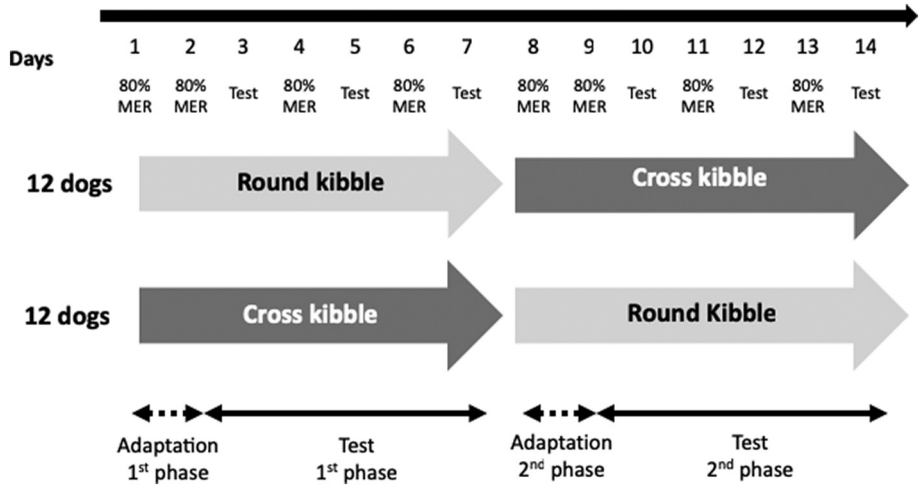

Fig. 2. Summary of the trial design for the voluntary food intake study. The test protocol was performed on 3 non-consecutive days for each study period, with 2 days adaptation before the first test day and food intake being limited to 80% of maintenance energy requirement in between.

Table 2
Characteristics of the dogs participating in the field evaluation.

Characteristic	Diet 1 cross kibble	Diet 2 cross kibble
Number of dogs	33	50
Sex	16 male (13 neutered) 17 female (14 neutered)	34 male (30 neutered) 16 female (12 neutered)
Weight (kg)	9.6 [3.1 to 15.2]	32.5 [5.3 to 62.5]
BCS	6 [6 to 8]	7 [6 to 9]
Age (years)	6 [1 to 13]	8 [2 to 15]
Previous diet	Diet 1: 30 dogs Diet 3: 3 dogs	Diet 2: 37 dogs Diet 4: 13 dogs

Diet 1: Satiety small dog, Royal Canin, Aimargues, France; diet2: Satiety Weight Management, Royal Canin; diet 3: Prescription Diet® Canine Metabolic Mini, Metabolic, Hill's Pet Nutrition, Topeka, KS, USA; diet 4: Prescription Diet® Canine Metabolic.

of 2 weeks. At the end of this period, owners again considered the occurrence of food-seeking behaviours using the same 4-point ordinal scale as before. In addition, owners compared chewing behaviour and speed of ingestion on the cross kibble with the dog's usual (round kibble) therapeutic weight loss diet using 3-point ordinal scales (Table 4). Owners also rated the amount of chewing behaviour on the cross kibble compared with their usual diet with three possible options: “no change from the old food”, “slightly more with new food”, and “markedly more with new food”. Similarly, owners subjectively rated speed of ingestion as: “no change from the old food”, “slightly slower with new food”, and “markedly slower with new food”. Given that the options for these final questions were unbalanced, in that they did not include an option for the original diet being better, no statistical analysis was performed (see below).

Given possible issues with recall bias, a sub-population of the dogs (14 in total) were enrolled on a controlled weight loss protocol at a specialist weight management clinic (Royal Canin Weight Management Clinic, University of Liverpool, UK). The owners of these dogs were asked again about their dog's food-seeking behaviour and speed of ingestion 3–4 weeks after the dog had returned to their usual diet. Specifically, owners were asked to rate which diet had induced most chewing behaviour and which had most slowed down speed of ingestion; for both questions owners could decide whether the round kibble was best, the cross kibble was best, or whether both diets were the same.

Table 4
Owner perception of chewing behaviour and speed of ingestion on the cross-kibble diets compared with round-kibble diets for dogs in study 3 (field trial).

Characteristic	All dogs	Diet 1	Diet 2
Chewing behaviour when consuming food			
No change from the old food	41 (49%)	15 (45%)	26 (52%)
Slightly more with new food	27 (32%)	12 (36%)	15 (30%)
Markedly more with new food	15 (18%)	6 (18%)	9 (18%)
Speed of ingestion of food			
No change from the old food	41 (49%)	18 (54%)	23 (46%)
Slightly slower with new food	24 (29%)	7 (22%)	17 (34%)
Markedly slower with new food	18 (22%)	8 (24%)	10 (20%)

Diet 1: Satiety small dog cross shape, Royal Canin, Aimargues, France; diet2: Satiety Weight Management cross shape, Royal Canin.

2.7. Data handling and statistical analysis

Statistical analyses were performed with three statistical software packages (JMP version 12 and SAS version 9.3, SAS Institute Inc., Cary, NC, USA; Stats Direct 3.1.14, Stats Direct Ltd., Altrincham, UK). The level of statistical significance was set at $P < .05$, and all analyses were two-sided. Palatability data were expressed as quantity of diet consumed (in grams), VFI was expressed on an energy basis (in kcal per $kg^{0.75}$ per meal), whilst meal duration was expressed as time (in seconds) to complete a meal of standard size (100% MER). For the field study, owner perception regarding chewing and ingestion speed decrease were expressed in proportions of dogs that experienced no change, little change, or a marked change in behaviour. Finally, food-

Table 3
Owner perception of food seeking behaviours, chewing behaviour, and speed of ingestion for dogs in study 3 (field trial).

Owner-observed food-seeking behaviour	Original (round) kibble	New (cross) kibble
Never, or just before meals	17 (20%)	27 (32%)
Just before and occasionally between meals	23 (28%)	22 (26%)
Just before and frequently between meals	20 (24%)	17 (20%)
Just after meals or all the time	23 (28%)	17 (20%)

seeking behaviour was scored using a subjective ordinal scale from 0 (no begging) to 3 (begging right after meal).

For study 1, palatability of the round- and cross-kibble versions of diet 2 were compared using a two-sided paired-*t*-test, with data for the small-size and all-size panels handled separately. Dogs that consumed < 10 g per meal (4 of 35 dogs), in total, were excluded from analysis. For study 2, linear mixed models were used for VFI and meal duration data when assessing the respective influence of diet, week, and meal with all their respective interactions (first and second order) on food consumption (over the 4 meals) and meal duration (first and second meals). The 2 × 2 × 4 and 2 × 2 × 2 factorial designs for food consumption and meal duration, respectively, were analysed using dog ID as a random term. Normality was assessed using Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling tests, whilst homoscedasticity of residuals was assessed with the White test. As a result, data were rank transformed before analysis. The studentised maximum modulus adjustment (Dunnett's T3 method) was used for post-hoc analysis in the presence of heteroscedasticity and to correct for alpha risk inflation (Dunnett, 1980).

For dogs in study 3, owner-observed food-seeking behaviour when eating the cross kibble (cross kibble diets 1 and 2) and original (round kibble diets 1 to 4) diets were compared using an exact test for paired proportions (Liddell, 1983). The same test was used for owner observations of chewing behaviour and speed of ingestion in the subgroup of dogs attending the specialist weight management clinic.

3. Results

3.1. Study 1: palatability

With dogs in the small-size panel, there was no significant difference in the food consumption of the cross-kibble version versus the round-kibble version of diet 1 (Fig. 3a; $P = 1.000$). In contrast, dogs from the all-size panel consumed significantly more of the cross-kibble version than of the round-kibble version of diet 2 (Fig. 3b; $P < .001$).

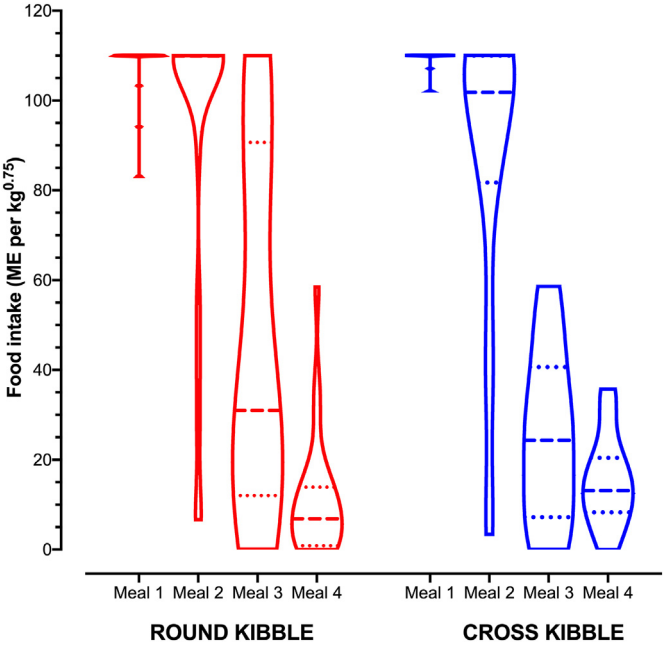

Fig. 4. Violin plot depicting sequential energy intake dogs during the voluntary food intake (VFI) study where dogs were fed the cross-kibble and round-kibble versions of diet 2. The 'violin' shapes depict both the range and distribution of data, with the width of the shape proportional to the amount of data at each point. The dashed lines represent the median, whilst the dotted lines represent the interquartile range. Dogs were offered food at 100% MER for a 15-min period over 4 consecutive meals separated by 45-min intervals. The test protocol was performed on 3 non-consecutive days for each diet and the results from each dog were averaged. Dogs consumed most of the available food from the first two meals with no difference between the two diets ($P = 1.000$ for both). At meal 3, VFI was significantly less for the cross-kibble diet than for the round-kibble diet ($P = .048$), but there was again no difference in VFI at meal 4 ($P = .117$), and no significant difference in total VFI over all 4 meals ($P = .37$).

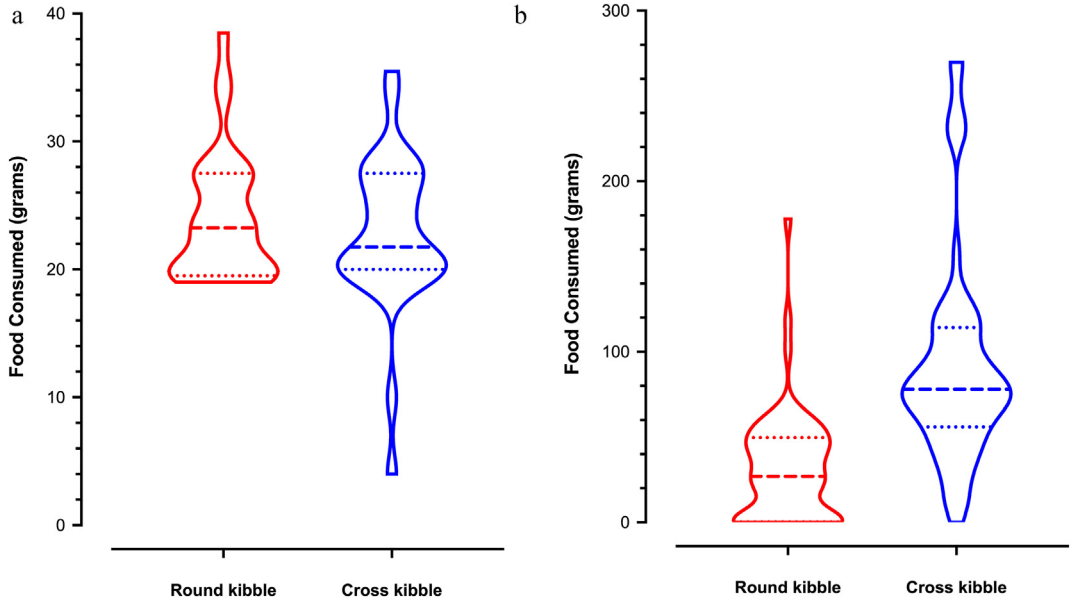

Fig. 3. Violin plot depicting consumption in dogs < 10 kg (a) and > 10 kg (b) of the cross-kibble (blue) and round-kibble (red) versions of diet 2 in the palatability study. The 'violin' shapes depict both the range and distribution of data, with the width of the shape proportional to the amount of data at each point. The dashed lines represent the median, whilst the dotted lines represent the interquartile range. The two diets were served, side-by-side in identical bowls, with the amount of each diet offered being half the daily energy requirements for each dog (55 kcal/kg$^{0.75}$). Bowls were withdrawn when the dogs had eaten half of the food offered, and the amount of each food consumed was then measured. Dogs > 10 kg consumed more of the cross-kibble diet than of the round-kibble diet ($P < .001$), but there was no significant difference in dogs ≤10 kg ($P = 1.000$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

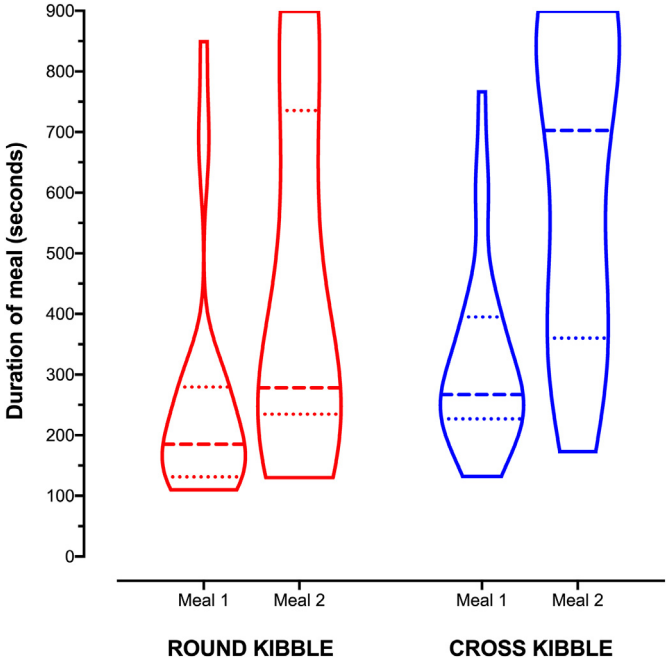

Fig. 5. Violin plot depicting consumption time for the first two meals of the consumption kinetics study. The 'violin' shapes depict both the range and distribution of data, with the width of the shape proportional to the amount of data at each point. The dashed lines represent the median, whilst the dotted lines represent the interquartile range. Dogs were offered food at 100% MER for a 15-min period for the two meals, which were separated by a 45-min interval. The test protocol was performed on 3 non-consecutive days for each diet and the results from each dog were averaged. Median (range) meal duration was significantly longer at both meals when dogs consumed the cross-kibble diet compared with the round-kibble diet ($P < .001$ for both).

3.2. Study 2: consumption kinetics

The VFI results for the eating kinetics for dogs in the consumption kinetics panel study are shown in Fig. 4. With both diets, dogs consumed most of the available food at the first two meals, and there was no difference between the two diets ($P = 1.000$ for meal 1 and meal 2). A significant decrease in median consumption was noted at meal 3, with dogs consuming less of the cross kibble than the round kibble ($P = .048$), but there was again no difference in VFI at meal 4 ($P = .117$), and no significant difference in total consumption over all 4 meals ($P = .370$). For the cross-kibble diet, median meal duration was 292 s (range 103 s to 900 s) for meal 1 and 650 s (range 120 s to 900 s) for meal 2, both of which were significantly longer than for meals 1 (186 s, range 89 s to 900 s; $P < .001$) and 2 (282 s, range 115 s to 900 s, $P < .001$) for the round kibble diet (Fig. 5).

3.3. Study 3: field trial

A total of 83 dogs were recruited, comprising a wide age range, with various breeds represented (Table 2). Owners reported less food-seeking behaviour when their dogs consumed the cross-kibble diets compared with their original (round-kibble) diets ($P = .020$; Table 3). This difference remained when dogs whose normal diet was either diet 3 or 4 were excluded ($P = .015$). Approximately half of the owners reported slightly (27/83, 51%) or markedly (15/83, 18%) more chewing behaviour with the cross-kibble diet compared with their original (round-kibble) diet (Table 4). Approximately half of owners also reported that speed of ingestion was slightly (24/83, 29%) or markedly (18/83, 22%) slower (Table 4).

The owners of 14 dogs attending the specialist weight management clinic were asked to rate the performance of both diets 3–4 weeks after their dog had returned to their original diet (Table 5). For chewing behaviour, 8 owners (57%) stated that the cross-kibble diet had performed best, none of the owners stated that the round kibble diet had performed best, whilst the remaining 6 owners (43%) stated that both diets had performed the same ($P = .031$). A similar pattern was observed for reductions in speed of ingestion, with 8 reporting superiority of the cross-kibble diet, 6 owners reporting no difference, and 0 owners reporting superiority of the round kibble diet ($P = .031$).

Table 5
Owner perception of which diets induced the most chewing behaviour and slowest speed of ingestion for field study dogs attending the specialist weight management clinic (field trial).

Characteristic	All dogs	Diet 1	Diet 2
Diet that induced the most chewing behaviour			
Round kibble best	0 (0%)	0 (0%)	0 (0%)
Both diets the same	6 (43%)	3 (38%)	3 (50%)
Cross kibble best	8 (57%)	5 (62%)	3 (50%)
Diet that slowed speed of ingestion the most			
Round kibble best	0 (0%)	0 (0%)	0 (0%)
Both diets the same	6 (43%)	3 (38%)	3 (50%)
Cross kibble best	8 (57%)	5 (62%)	3 (50%)

Diet 1: Satiety small dog cross shape, Royal Canin, Aimargues, France; diet2: Satiety Weight Management cross shape, Royal Canin.

4. Discussion

The three studies reported here have assessed the effects of a cross-kibble shape on palatability, voluntary food intake, speed of ingestion, and owner perception of their dog's behaviour when consuming this shape as part of a weight loss programme. Study 3 was a field trial that sought owner opinions of food-seeking behaviour, chewing behaviour, and speed of ingestion. Compared with a round-shaped kibble, the crossed-shaped kibble, significantly reduced food-seeking behaviours, induced more chewing behaviour and slowed speed of ingestion. These findings were supported by studies 1 and 2, which were undertaken in healthy kennelled dogs where, despite equivalent palatability, speed of ingestion was slower with the cross kibble.

A link between ingestion speed and satiety has been demonstrated in humans, with slower ingestion and longer meal duration leading to improved satiety (Ferriday et al., 2015). However, since direct assessment of appetite and satiety is not possible in dogs (Weber et al., 2007), we instead chose to measure VFI and meal duration in a group of healthy kennelled dogs. In a feeding experiment where 4 meals were offered at 45-min intervals, duration of the first two meals was significantly longer for a crossed-shaped kibble compared with the same food but with a traditional round-shaped kibble. Although not measured directly, the slower food intake is likely to be the result of a greater requirement to chew this kibble compared with a round kibble that can be more readily swallowed. Further, VFI at the third meal was significantly less with the cross kibble, although VFI was not less overall. It is tempting to suggest that the reason for the decreased VFI at the third meal was the decreased speed of ingestion during the two preceding meals. However, rather than speed of ingestion, this effect might instead have been due to the slightly lower kibble density and larger volume; in this regard, other studies have suggested that VFI can be decreased by feeding kibbles expanded by air (Serisier et al., 2014). Nonetheless, it should be noted that there was no reduction in VFI at the fourth meal and, total VFI over all four meals did not differ. Therefore, compared with other effects, such as macronutrient content (Weber et al., 2007; Hours et al., 2016), the effect of altering kibble shape on total VFI is relatively minor. In light of this, it is not clear what benefit the impact of feeding this kibble either in preventing weight gain or facilitating weight loss. As a result, further studies are required.

When assessing VFI of any diet, it is vital also to assess palatability,

because consumption can be adversely affected if a dog is reluctant to eat it. This was undertaken in study two, where two dog panels, one with dogs ≤10 kg and the other with the dogs of a range of sizes. The reason that small dogs were included in both panels was because availability of diet 1 (designed for small dogs) varies, with some practices preferring to stock only one diet. Therefore, it is necessary to ensure that palatability in small dogs is acceptable when fed both the conventional and small dog versions. The fact that dogs of the all-size panel selected the cross kibble in preference to the round kibble, when offered the two in a side-by-side feeding trial, confirms that poor palatability was not the reason for differences in consumption kinetics. The reason for this observed effect is unclear since the cross kibble and round kibble versions of each diet had an identical formulation, and since we did not observe the same result in dogs of the small-size panel where the consumption of the round- and cross-kibble diets were similar. One explanation is that the cross-kibble formulation was novel, and this encouraged dogs in the all-size panel to consume it in preference over the conventional kibble shape. An alternative possibility is that dogs selected this food in preference because of the greater work required when consuming it. Although counter-intuitive, domesticated dogs are suggested to be contra-freeloaders in that, given the choice, they prefer to work for their food rather than not (Osborne, 1977). Further studies are required to explore the reasons for this difference.

The study has a number of limitations that should be acknowledged. First, the consumption kinetics study was the fact that it was undertaken in healthy dogs from a kennelled environment. As a result, a third study was conducted to gather complimentary information in overweight pet dogs undergoing controlled weight loss using a therapeutic weight loss diet. Whilst the data gathered were subjective, given that they were based upon owner opinions, the findings broadly support those observed in the research colony studies. Notably, owners observed that speed of ingestion was slower, and dogs tended to chew food more with the cross kibble than with the round kibble. Further, owners reported that signs of food-seeking behaviour were reduced when feeding the cross kibble. Of course, some dogs' original therapeutic diet was made by a different manufacturer and, as a result the diet formulation differed as well as the kibble shape. However, significant differences remained when these dogs were excluded from the analysis. Second, the study was 'open-label', in that owners were aware of the different kibble shape, and this might have influenced the opinions obtained. For example, on seeing the different kibble shape, owners might assume that it would require greater chewing and increase ingestion time even if it did not. Further, owner responses might have been subject to recall bias, given the way that the questions were administered. Fourth, some of the questions asked were not balanced, for example, an option for the original diet to be superior was not given (Table 4). Given this limitation we only performed statistical analyses on questions where which did not suffer from this issue, for example, questions on chewing behaviour and speed of ingestion (Table 5). Nevertheless, the study should be considered preliminary in nature, and results interpreted with caution. A fifth study limitation was the fact that only female dogs were included in the panels of dogs used for studies 1 and 2; this was because most of the dogs were female at the research sites where the studies were conducted, in order to minimise potential issues with aggression and male dominance with their colonies. It is possible that different results might have been obtained had male dogs been included and, as a result further studies are recommended.

Additional limitations should be acknowledged, most notably, the fact that all studies were short-term in nature. As a result, we cannot be certain that observed changes in consumption kinetics would persist long term. For example, over time, dogs might learn to eat the cross kibble more quickly, diminishing its benefit, whilst familiarity might also influence the apparent palatability of the new kibble. In a similar manner, the changes that owners observed in food-seeking behaviour might diminish once the novelty of the new kibble shape had worn off. Therefore, longer-term studies are now required to determine whether the apparent benefits persist or diminish, and possible effects on outcomes of a weight management programme, including owner compliance.

5. Conclusion

In conclusion, these studies have suggested that altering kibble shape can decrease ingestion speed without affecting palatability, resulting in a significant decrease in food-seeking behaviour in dogs. Further studies are needed to confirm weight loss results and compliance with the weight loss programme with long-term use of the cross-shaped kibble diet.

Competing interests

All the authors are current or past employees of Royal Canin, except A.J.G., whose academic post at the University of Liverpool is financially supported by Royal Canin. All the authors were involved in the study design, in the collection, analysis and interpretation of data, in the writing of the manuscript, and in the decision to submit the manuscript for publication.

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